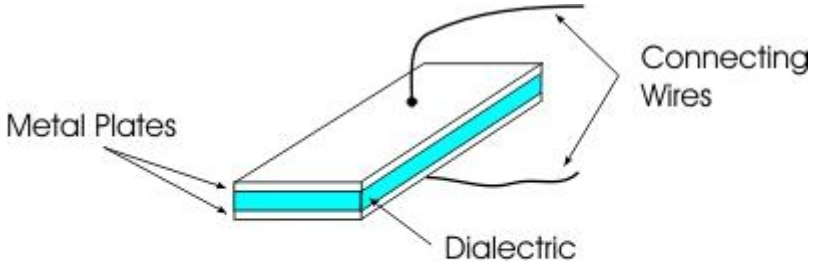
CAUTION!
A high-quality capacitor can hold a charge for long periods of time.

To prevent a painful shock, the capacitor must be discharged before its removal.

What Is A Capacitor?



Dialectric Capacitor

For HVAC technicians, a capacitor is simply a device that stores energy. It charges and discharges 50/60 times a second. On Run-Start-Common devices, it is connected between the Run and Start windings.

There are several reasons capacitors are used in the HVAC industry:

1. Efficiency - A capacitor attempts to correct a poor Power Factor by adding Capacitance Reactance. Since a compressor or fan motor is an inductive device with Inductive Reactance, a capacitor will largely zero the reactances, resulting in a compressor or fan motor that runs cooler and uses less electricity.

2. Cost - Older compressors and fan motors did not use capacitors at all. Instead, they were built much better than today's motors, which cost more in the manufacturing process.

3. Start-up Boost - Run and Start capacitors will give an initial start boost. The run cap provides higher efficiency and is in-circuit all the time, while the start cap is typically switched out after startup with a potential relay or centrifugal switch.

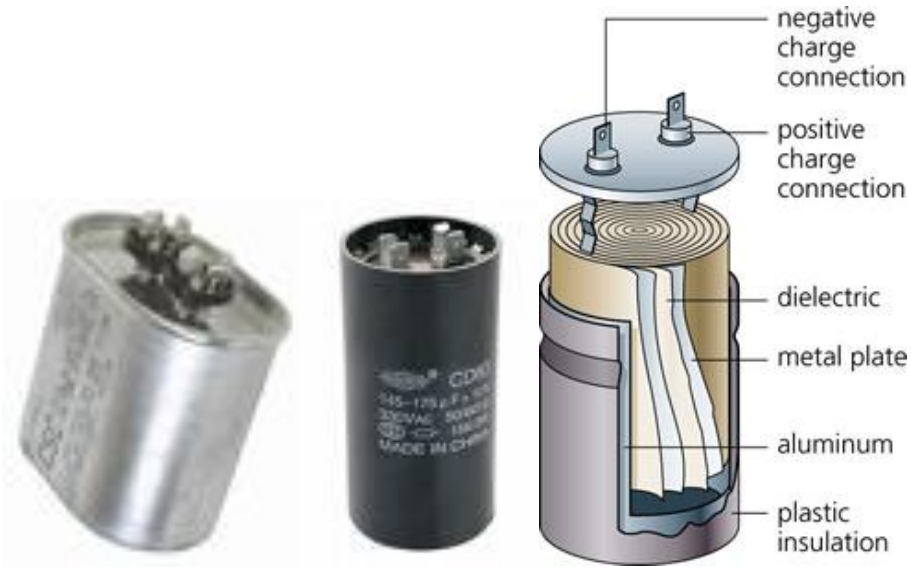
There are two "plates" separated by a material called a dielectric. The dielectric can be made from many materials, but is generally an insulator. As a current is applied, separate charges build up on the plates. The resultant energy of the charges is then stored in the field between the two plates.

Essentially, what is happening is that there are two separate charges that are being controlled in an electric field. Depending on what you want to use the capacitor for, there are various materials that can be used as a dielectric. If a very high efficiency is desired, a vacuum is the most often specified dielectric.

Electrodes serve as the "plates." As the dielectric is a vacuum, there is very little resistance in the system, giving high efficiency.

Radio systems are a good example of a use for this type of dielectric because efficiency and heat characteristics are of paramount importance. If tuning of the radio is an application of consideration, then an air dielectric may be a good choice. If high temperatures and voltages are a consideration, mica and glass make for excellent dielectrics. Control of heat is relatively simple, and the materials are abundant. One of the better characteristics of dielectrics is that they can be controlled to provide the amount of insulation between the "plates" that is desired. If a wire or series of wires are used as the dielectric, they can be twisted or untwisted to the degree of insulation desired.

HVAC Capacitors in General



- Rated by both Capacity (2 mfd, 7.5 mfd, etc) and Voltage (370V, 440V)
- Run capacitors are rated for microfarad ratings from 3-50 uf
- Start capacitors have much higher ranges up to 800 uf
- The rated size should not be changed since the motor operates at maximum efficiency using the specified size
- If necessary, the Voltage rating can be higher than specified, but not lower
- Replace the capacitor when replacing a motor
- A capacitor can hold a charge for a long time - be careful!
- A run capacitor will increase run-time efficiency of the motor
- A run capacitor will give it an initial start boost
- Capacitors reduce manufacturing cost of the motor
- Capacitors are only used for single-phase motors
- Capacitors consist of insulator between two metal plates

Run Capacitor Uses

- Air handler blower motors
- Induced draft or forced draft fan motors
- Condenser fan motors
- Compressors

Start Capacitor Uses

- Provide added boost to get compressors started
- Usually disengages after compressor is started
- Requires a special relay to disengage the start capacitor after startup
    - Potential Relay - Most common
    - Current Relay - Least common. This type of relay requires proper orientation.

Dual Run Capacitor

- Both caps exist in a single housing for a compressor and a fan motor
- Does not include the start capacitor

Symptoms of a Bad Run Capacitor

- The motor will not turn
- The motor will probably be buzzing until the overload kicks in (kicks out?)
- Manual assist to get the fan rotating MIGHT work

- CAUTION: The motor could be bad, especially if OL has opened up a few hundred times before - This condition exists when the homeowner does not call the contractor right away

PCB Issues

- PCB = Polychlorinated Biphenyl Oil
- Old capacitors may have PCB inside of them
- PCB's cause cancer, and are considered dangerous
- New capacitors have "No PCB's" stamped on their casing
- If no legend, then IT HAS PCB'S !!!
- PCB's requires EPA-certified disposal

Capacitor Check with Ohmmeter

- Use non-auto-ranging meter (this will not work if auto-ranging)
- Discharge the capacitor
- Put your multimeter in the highest range
- Connect ohmmeter leads to capacitor - observe polarity if electrolytic
- Observe 0 ohms initially, then a slow climb to infinity
- Reverse the leads - observe a slow decline to 0 ohms
- NOTE: Passing this test does not mean the cap is good (not a Load Test). However, failing this test DOES mean a bad cap.

Measure Rating of High-uf Capacitors

While system is running, take Voltage and Amperage readings.
Then use the following formula:

$$MFD = \frac{Amps * 2654}{Volts}$$

Volts \ Amps	2	3	4	5	6	7	8	9	10	11	12	13	14	15
315	17	25	34	42	51	59	67	76	84	93	101	110	118	126
320	17	25	33	41	50	58	66	75	83	91	100	108	116	124
325	16	24	33	41	49	57	65	73	82	90	98	106	114	122
330	16	24	32	40	48	56	64	72	80	88	97	105	113	121
335	16	24	32	40	48	55	63	71	79	87	95	103	111	119
340	16	23	31	39	47	55	62	70	78	86	94	101	109	117
345	15	23	31	38	46	54	62	69	77	85	92	100	108	115
350	15	23	30	38	45	53	61	68	76	83	91	99	106	114
355	15	22	30	37	45	52	60	67	75	82	90	97	105	112
360	15	22	29	37	44	52	59	66	74	81	88	96	103	111
365	15	22	29	36	44	51	58	65	73	80	87	95	102	109
370	14	22	29	36	43	50	57	65	72	79	86	93	100	108
375	14	21	28	35	42	50	57	64	71	78	85	92	99	106
380	14	21	28	35	42	49	56	63	70	77	84	91	98	105
385	14	21	28	34	41	48	55	62	69	76	83	90	97	103
390	14	20	27	34	41	48	54	61	68	75	82	88	95	102
395	13	20	27	34	40	47	54	60	67	74	81	87	94	101
400	13	20	27	33	40	46	53	60	66	73	80	86	93	100
405	13	20	26	33	39	46	52	59	66	72	79	85	92	98
410	13	19	26	32	39	45	52	58	65	71	78	84	91	97
415	13	19	26	32	38	45	51	58	64	70	77	83	90	96
420	13	19	25	32	38	44	51	57	63	70	76	82	88	95
425	12	19	25	31	37	44	50	56	62	69	75	81	87	94
430	12	19	25	31	37	43	49	56	62	68	74	80	86	93
435	12	18	24	31	37	43	49	55	61	67	73	79	85	92
440	12	18	24	30	36	42	48	54	60	66	72	78	84	90
445	12	18	24	30	36	42	48	54	60	66	72	78	83	89
450	12	18	24	29	35	41	47	53	59	65	71	77	83	88

Rules for Capacitor Replacement

1. Voltage must be EQUAL TO or GREATER than the cap being changed
2. Start Cap must be +- 20% of mfd
3. Run Cap must be +- 10% of mfd

- If the Start Cap is UNDERSIZED, the motor might not start.
- If the Start Cap is OVERSIZED, the high start current might burn out the start winding.
- If the Run Cap is incorrectly sized, the Power Factor will suffer, resulting in lower effeciency, higher operating costs, and possible motor damage.

THE ROLES OF A CAPACITOR

Capacitors are a very important component of modern HVAC systems, as they are used in ac motors to provide starting torque and to improve the motor's running efficiency. For both functions, the capacitors are connected in series with the start and main windings of the motor.

Depending on the function of the capacitor within the ac motor circuit, it can be called a start capacitor or a run capacitor. The start capacitor provides the motor with the torque needed to move the motor from standstill, and then automatically disconnects itself from the circuit. The run capacitor helps to maintain the rotational field under optimum conditions, helping the motor to run more efficiently at a higher power factor; it remains connected at all times. This is the reason it is called a run capacitor.

These capacitors generally are found in single-phase ac motors. This is because a single-phase ac source rises and falls from zero very rapidly, and the capacitor helps by producing a current-to-voltage lag on the windings. Since this current builds up more slowly, it gives time to the motor armature to react to the rotational field.

Capacitors are sort of like batteries — both store electrical energy, but they work differently. A battery uses chemicals to produce electrical energy and release it very slowly through a circuit, sometimes taking several years to disperse all the energy (in the case of a watch battery, for instance). A capacitor, which stores energy in the form of an electrostatic field, generally releases its energy much more rapidly — often in seconds or less. This can make a large, charged capacitor extremely dangerous if used or handled improperly.

When capacitors do not meet the performance ratings specified on their labels, and when used with motors in HVAC systems, they can severely damage the motors by:

- reducing the speed of the motor, which:
  - increases the motor's temperature,
  - causes bearing wear and insulation breakdown, and
  - increases the noise

- lowering the motor's efficiency, which causes additional energy consumption and costs for the customer

- creating improper operation of the entire equipment, which;
  - ❖ results in improper cycling
  - ❖ increases system noise and
  - ❖ provides unwanted stress on other system components.

Capacitance Calculations

Series connection:

If, for example, two 5 mfd 370 VAC capacitors are wired in series, the following formula will show equivalent capacitance and voltage rating they produce when connected this way.
MFD = 1 / (1/Capacitor one) + (1/Capacitor two)
= 1/(1/5 + 1/5)
= 2.5 Mfd.
Also, the two 370 VAC capacitor ratings add together in a series connection giving 740 VAC total capability.

Parallel connection:

If the two capacitors are wired in parallel the following formula will show the Mfd. result. Mfd. = Capacitor one + Capacitor two
= 5 + 5
= 10 Mfd.
In a parallel connection, the two 370 VAC capacitor ratings do not add together, so the total capability is still 370 VAC.

Resistors vs Capacitors in Formulas
A convenient method of remembering the formulas is to view oppositely.

Note! Capacitors in parallel uses the same formula as resistors is series.

Capacitors is series use the same formula as resistors in parallel

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